SOFTWARE GSPARALW - Version C

USER MANUAL

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QUICK INSTALLATION AND SURVEY

Installation

Insert the CD in its drive. If its contents do not self display, open it with **Windows Explorer**.

To install **GSPARALW** on your hard disc, double-click on the installation programme **InstalParalW.** It will create a folder named **GSREPER** (if not yet existing) and will copy in it the software. It will also copy six auxiliary files named **ParalWD1...4.dat** and **ParalWN1...2.dat** containing the tolerances per NF E and DIN. In addition, it will create a short cut and its icon on your computer desktop ; you will just have to double click on the icon to run **GSPARALW**.

If convenient, the file **gsparalw.exe** can be moved manually anywhere on your hard disc.

Survey

The organigram of **GSPARALW** is visible from all pages (except Help pages) by clicking on the red button **O** located in the upper left corner. From it you can see where you are in the software and where to go.

Help in line is available when necessary by clicking on menu **Help**. In addition, some datum fields provide a specific help ; when passing over them with the cursor, the mention "F1 = Help" is displayed. Focus now the field by clicking on it and press key **F1**.

IMPORTANT 17-11-2006

This software cannot be transferred or copied to the benefit of any other company or people without the Author's permission. Its use is subject to your acceptance of the conditions accessible from the first page of the software.

FOREWORD

GSPARALW Version C is an efficient software to deal with all the problems involved in parallel gearing, spur or helical, external or internal, including simple epicyclic trains.

It allows quick and accurate determination of the following dimensions :

- reference and operating pitch diameters, tip and root diameters, base diameters and helix angle.

- minimum operating radius when engaged with another element.

- transverse contact and overlap axial ratios.

- span dimensions and dimensions over pins .

- tolerances as per french standard NFE 23-006, german standard DIN 3062 and ISO 1328-1 and 2.

In addition it :

- advises all kinds of interference or undercutting.

- allows automatic determination of optimum basic rack shift coefficients to prevent undercutting and exactly balance the slide-roll ratios of pinion and wheel.

- checks the full suitability of a shaper to cut an internal wheel.

- draws and prints the section of the pinion and wheel tooth.

- calculates the bearing loads.

- determines the cutting times.

- allows to visualize the meshing cycle.
-

Help in line is available whenever possible and necessary. Click on Menu ***Help*** or button **?**. In addition, a specific help in line is available for certain capture fields. These fields are advised by a bubble **F1=Help** displayed when the cursor passes over the field. Click on the field to focus it and press key **F1**. On the **DATA** page, the menu **Help** gives access to an option allowing a predetermination of the numbers of teeth and module for a given torque to be transmitted.

When a gear or a pair of gears has been designed, GSPARALW allows recording on disc of all dimensions and tolerances for a future recall.

With the extension LOAD CAPACITY it determines the torque and power capacity according to :

- NFE 23-015 french standard.

- AGMA 2001-B88 american standard of September1989. With possible application of the Miner'rule for variable loadings.

- ISO 6336.

- method of G. HENRIOT proposed in his book TRAITE THEORIQUE ET PRATIQUE DES ENGRENAGES.

GSPARALW makes them easily accessible to engineers who are not specialized in gearing and will certainly prove helpful even to specialists

LIMITS

GSPARALW is suitable only for involute parallel axis gears, either spur or helical and spur internal. Low tooth external gears as STUB are accepted.

RUNNING GSPARALW

GSPARALW is protected by two codes, the first one referring to the dimensional section, the second one to the extension LOAD CAPACITY

If you are in a trial period and therefore do not know the codes, you however can have access to all functions and options of GSPARALW, including the extension LOAD CAPACITY, but only odd number of teeth will be accepted.

When numbers in parenthesis are displayed, they refer to the corresponding paragraphs **( )** of this manual.

After having choosen either conventionnal gears or epicyclic train a first menu is displayed with the following options :

- **a new case** : to be selected to deal with a new problem. Recording will be possible for later recall.

- **read ... from disc with modifications** : allows reading of a previously recorded case with possible modification of data.

- **read ... from disc without modifications** : allows reading of a previously recorded case without modification of data.

- **replace worn out gears** : to determine the dimensions to be given to gears to replace existing worn out.

- **delete ... on disc** : to delete an element or train previously recorded. If the element to be deleted has been recorded with a mating element, both will be deleted.

- **save the file ... .dat** : it is recommended to save periodically the files PARGEARW dat and PLANETW.dat containing the records. If necessary it will be then possible to reload the records from the disquette to the directory GSREPER.

- **exit GSPARALW** : if a case has been dealt with, GSPARALW will ask if you wish to record it before leaving.

In case of option 1, you will have to choose between one external or internal gear, or two external or internal gears.

In case of options 1 and 2, GSPARALW displays an editing page. Select first the type of gear(s), then the desired options, then fill the other fields. With Stub teeth the options “Manual rack shift” and “Free centre distance” are only accessible.

Each element can be identfied by a reference (30 characters), a number (8 characters) and an index. These identications will be used for a later recall.

RECORDING ON DISC

Each time a new case has been dealt with, or when an existing case has been modified, GSPARALW will ask if you wish to record for a later use.

When the case dealt with comprises two elements, pinion and wheel, each one is recorded under its own identificators but when one of them is later recalled its mating element is also read. If you omitted the reference and number, they will be asked for before recording. If you just have modified an existing case, it will be recorded under the former reference and number.

READING FROM DISC

In case of options 2, 3 and 5, GSPARALW displays a selecting grid.

Sorting is carried out either with alphabetic references, or increasing numbers, or increasing modules.

On each line can be seen the reference, the number, the index if any, the normal module, the number of teeth followed by the letter **I** if internal gear, the helix angle followed by the letter **R** or **L** according to the helix hand, the number of teeth of the mating gear if any followed by the letter **I** when internal or **rack** if a rack.

When the record comprises two elements, both are read.

DIMENSIONAL SECTION

DATA SYMBOLES AND UNITS

All dimensions in mm unless otherwise specified, loads in Newton, torques in N.m, powers in kW and angles in decimal degrees.

Subscript 1 refers to pinion, subscript 2 to wheel and subscript 0 to tool.

Aw centre distance at zero backlash. When the algebraic sum (external gears) or difference (internal gears) of the basic rack shift coefficients is not zero, it is taken into account. When the pinion is associated to a rack, a_w is the distance from the pinion centre to the rack reference line.

b face width.

d reference pitch diameter.

da tip diameter. When the sum (external gears) of the basic rack shift coefficients is not zero, this dimension may be slightly reduced to maintain the bottom clearance. It may similarly be slightly increased with internal gears to prevent interference.

db base diameter.

dw operating pitch diameter.

F1,2,3,4 load on bearing 1,2,3,4. See Help in line.

K number of teeth for span gauging.

L1,2,3,4 distance from centre plane to bearing 1,2,3,4. Help in line.

mn normal module.

rt0 tip radius coefficient of cutting tool. See Help in line.

sna normal crest thickness. When the data entered lead to a value smaller than 0,3 mn, it is advised. When they lead to a negative value (sharp crest), it is rejected. See later.

W span gauging over K teeth.

x basic rack shift coefficient. It is positive when the basic rack reference line does not intersect the reference pitch circle diameter, negative when it does. This definition is applicable to both external and internal gears.

y0 tool addendum coefficient. See Help in line.

alphan normal pressure angle.

beta helix angle.

betab base helix angle.

delta 1,2,3,4 angle of load F1,2,3,4. See Help in line

epsilon $_{alpha}$ transverse contact ratio.

(1)
epsilon $_{beta}$ overlap axial ratio. Should be > 1 to provide full advantage of helical gearing. When epsilon $_{beta}$ < 1 the load capacity of helical gears is impaired. Increase helix angle or face width or choose a smaller module to make epsilon $_{beta}$ > 1.

(2) AUTOMATIC DETERMINATION OF RACK SHIFT COEFFICIENTS

The option "automatic determination of rack shift coefficients" not only prevents undercutting but optimises the rack shift coefficients to balance exactly the slide-roll ratios of pinion and wheel.

(3) This option is accessible as well with free or imposed centre distance, for external or internal gears. For the latter it is however quite satisfactory to give both pinion and wheel a positive coefficient of 0.4 to 0.5 normal module.

Incidentally the slide-roll ratio, the value of which is displayed, characterises the resistance to wear : the closer it is to zero, the closer the contact is to pure rolling and therefore the smaller is the wear. The balance results in an equal sharing of wear between pinion and wheel.

EXTERNAL GEARING

(4) When the data entered, number of teeth, helix angle, rack shift coefficient lead to undercutting with rack cutter or hob, it is advised. It is then possible either to continue with undercutting, or to go back to modify one or more parameter(s) and cancel undercutting. Clearly this last option is strongly recommended. If however undercutting is accepted, it is suggested to draw the tooth section to appreciate its amount.

(5) When the data entered lead to a tip thickness smaller than 0.3 mn, it is advised. This value is normally a minimum especially with case hardened gears.

(6) When the data entered lead to a negative tip thickness (sharp crest) it is rejected.

INTERNAL GEARS

Internal gears are subject to specific restrictions or interferences examined below.

Limitation of tip diameter da2

When the flank of the mating pinion is generated by a rack or hob, the involute profile extends downward to a definite radius depending on the rack shift coefficient, the tool addendum and the tool tip radius. But if the wheel tooth total height is held normal (2 normal module), it may require that the arc of involute of the pinion tooth flank extends lower than actually generated. In this case, GSPARALW automatically increases da2 by a small amount just preventing the interference.

In the case of a shaper, GSPARALW gives the radius to which the arc of involute should extend to generate the wheel profile down to its tip.

All these calculations are carried on from nominal dimensions. When some backlash is provided by the wheel, the shaper is fed slightly deeper. The result is a slight easing at the wheel tooth tip which is negligible and does not affect the wheel behaviour.

(7) Trochoïdal interference (Fig. 1

When the difference between the pinion and wheel numbers of teeth is too small, this specific interference may occur. In this case the pinion (or shaper) tooth tip trims the wheel tooth tip. This type of interference is advised and the amount of trimming is given as well for the pinion as for the shaper. With a pressure angle of 20° a difference of 8 teeth between pinion (or shaper) and wheel is usually sufficient to prevent interference.

(8) Radial engagement (Fig. 1

When the difference between the pinion and wheel numbers of teeth is not sufficient, it may not be possible to engage the pinion radially in the wheel, but only axially. In the case of a shaper it is clearly impossible to make axial engagement and consequently trimming of the teeth would result..

This is advised as well for the pinion as for the shaper. In this latter case the amount of trimming is given.

(9) Interference at tooth bottom

When the shaper addendum is not sufficient to generate the wheel profile to the necessary height, an interference may occur when meshing with the pinion. This is exactly the same type of interference as that existing at the tip, but now at the bottom. GSPARALW advises this type of interference. Another shaper can then be selected or, alternatively, reduce the pinion tip diameter by an amount equal to two times the interference.

All these calculations are carried on from the nominal dimensions. If some backlash is provided by the wheel, the shaper is engaged slightly deeper and some safety margin will result.

ALLOWANCE ON SPAN DIMENSIONS W/K TEETH

Allowances on dimension W/K teeth controling the backlash are entered on the editing form. If preferred they can alternatively be entered from the form tolerance NFE 23-006. The corresponding dimensions over rollers are displayed. Note that negative allowances provide backlash with external gears but positive allowances are required with internal gears.

(10) DRAWING OF NORMAL TOOTH SECTION

External gears

GSPARALW draws the section in a normal plane as generated by a rack or hob. The fillet shape is true and it is possible to appreciate the effect of undercutting. For helical gears, the section is that of the spur gear having the virtual equivalent number of teeth. Errors involved are negligible and always smaller than the screen resolution. Drawing and printing of several teeth are available only with spur gears. For helical gears indeed it would be necessary to draw the transverse section which would not be representative of the form and resistance to failure.

Internal gearing

GSPARALW draws only the arc of involute : the fillet is not drawn since widely depending on the shaper data. It is in addition of no interest since the bending strength of an internal wheel is never critical.

In both cases the reference pitch circle is drawn.

Printing

Enter the enlargement factor (scale) of printed tooth.

MESHING CYCLE

This option draws the surface of contact and the teeth in the transverse plane. The teeth can be moved within a cycle to examine the meshing. All necessary informations are given through the “Help in line”.

BEARING LOADS

Distances L1, 2, 3, 4 are measured from centre plane of gear to bearing 1, 2, 3 or 4. See Help in line.

(11) It is important to enter these distances as positive or negative in accordance with the figures obtained with the Help in line. Bearings below the centre plane of gears involve negative values of L. The direction of rotation and helix hand applie to the pinion. When the wheel is driving (speed increaser), reverse the direction of rotation.

GSPARALW displays for each direction of rotation and helix hand the load applied to each bearing for a unity torque at the pinion. Multiply the figures displayed by the actual torque to obtain the actual load.

GSPARALW also displays the load angle (dec. degrees) for each bearing as measured from the centre line.

(12) Tolerances NFE 23-006

Tolerances according to the french standard are easily accessible as well for the pinion as for the wheel.

Allowances can be applied either to the span dimensions W/K teeth or to the tooth normal thickness. Some comments follows.

Most standard allowances are negative in order to provide backlash. If they were applied to the span dimensions W/K teeth of internal gears the result would be seizure instead of backlash. This is why the application to the span dimensions is possible only with external gears. If the application is selected to the circular thickness, backlash is obtained as well with external as internal gears.

It will be noticed that when the application is selected to the thickness, the allowances have not the same values on the form “tolerances” or “dimensions”. This is because in the former case they apply to the thickness while in the latter they apply to the span dimensions and are therefore multiplied by the cosine of the normal pressure angle. For the same reason, the signs are different in the case of internal gears ; a reduction of the thickness results in an increase of the span dimensions.

(13) Tolerances DIN 3962 (August 1978)

Tolerances according to the german standard are easily accessible as well for the pinion as for the wheel. Translation of the german terms are given hereunder without any liability.

Profil-Formabweichung ff : profile shape error

Profil-Winkelabweichung fHalpha : profile angle error

Profil-Gesamtabweichung Ff : profile total error

Teilungs-Einzelabweichung fp : individual pitch error

Eingriffsteilungs-Abweichung fpe : gear pitch error

Teilungssprung fu : pitch error

Teilungs-Gesamtabweichung Fp : pitch total error

Teilungs-Spannenabweichung über 1/8 Umfang Fpz/8 : pitch error on 1/8 revolution

Rundlaufabweichung Fr : radial runout error

Zahndickenschwankung Rs : allowance on tooth thickness

Flankenlinien-Gesamtabweichung Fbeta : flank line (helix) error

Flankenlinien-Winkelabweichung FHbeta : flank line (helix) angle error

Flankenlinien-Formabweichung Fbetaf : flank line (helix) shape error

Teilungs-Spannenabweichung Fpk : pitch error over N teeth

ISO Tolerances ISO 1328-1 and 2

Tolerances according to ISO are easily accessible as well for the pinion as for the wheel.

(14) IMPORTANT : Values displayed are those found in the standard issued by the french Association Française de normalisation (AFNOR) under reference E 23-007-1 et 2. However this document incorporates two mistakes :

1°/ Total pitch error Fp for 1600 <dia.<=2500, 40<mod.<=70, precision class 11.

The (wrong) value given by the standard is 603 when the correct value is 630.

2°/ Total profile error Falpha for 6000<dia.<=8000, 16<mod.<=25, precision class 9.

The (wrong) value given by the standard is 113 when the correct value is 133.

GSPARALW displays the correct values, not those given by the french edition.

GSPARALW displays the cumulative pitch tolerance for all teeth and for half the circle. Normally it is however checked on only 1/8 of the total number of teeth.

EPICYCLIC TRAINS

Details to use this option are accessible on line by clicking on menu ***Help*** or when existing on icon **?**.

Following are some comments regarding this type of gearing.

Ratio of train It is equal to $\frac{\text{Number of teeth in crown}}{\text{Number of teeth in sun}} + 1$

with the sun driving and the crown fixed.

Number of teeth The numbers of teeth in sun and crown, which determine the train ratio, are normally entered. The normal corresponding number of teeth in planets is automatically displayed. When necessary, for example to cure undercutting, it can be reduced or increased by one unit. In order to ensure equidistant location of planets, the sum (number of teeth in sun + number of teeth in crown) divided by the number of planets must be an integer. If the entered numbers of teeth do not comply with this rule they are refused.

Automatic basic rack shift When this option is selected, the sun and planets rack shifts are optimised by equalling their slide-roll ratios. The crown rack shift is then determined from the planet one. The sun planet meshing is preferred because the load capacity of the planet crown meshing is normally largely in excess of the other one.

Recording The train data are saved separately from those of conventionnal gears in a file named PlanetW.dat located in the directory named GSREPER.

EXTENSION "LOAD CAPACITY"

Epicyclic trains

The displayed load capacities take in account the total number of planets. It is assumed that the load is perfectly shared by the planets, this of course being never achieved. It is the responsibility of the designer to reduce the values displayed in accordance with the actual degree of misbalance, having in mind that a satisfactory sharing can be obtained with 2 and still more 3 planets but that with more planets the sharing can be only very poor.

The calculations are based on the relative speeds of the elements. All indeed behave as if the planet carrier was fixed and the sun speed being that relative to the sun carrier. This relative speed is equal to

$$Nrelative = N \left(1 - \frac{1}{K}\right)$$

where K is the train ratio as determined above.

Account is of course taken of the sun and crown number of meshings multiplied by the number of planets, and of the number of planet meshings multiplied by 2.

The four methods proposed for the evaluation of the torque and power capacity of parallel axis gears are applicable either to internal (except NFE 23-006) or external, spur or helical, with involute profile.

The gear capacity is limited either by surface stress (pitting resistance or wear) or bending stress (bending strength). The load capacity of a pair of gears should therefore be determined using four calculations, for pitting and for bending of both pinion and wheel.

These four methods do not allow calculation of bending strength of internal gears since this type of gear is normally not subject to this kind of bending failure.

GSPARALW allows easy determination in a few seconds of the corresponding ratings with however the following limitations :

- the working height of the tooth must be 2 normal modules. Low tooth such as STUB are not allowed.

- the profile must be involute without transverse or axial modification such as crowning or tip easing or semi-topping.

- the profile must be free of any kind of undercutting or interference.

- no service factor is taken into account. The designer should therefore appreciate and apply it to the results.

DATA SYMBOLS AND UNITS

Unless otherwise specified all dimensions are in mm, loads in Newton, torques in N.m and powers in kW.

Subscript 1 refers to pinion, 2 to wheel.

b face width of the narrowest element.

E modulus of elasticity (N/mm²). See Help in line.

HB Brinell hardness (ball dia. 10 - 3000 Kg). See Help in line.

M1 allowable pinion torque.

n1 pinion speed (r.p.m.).

P power.

z2c operating number of teeth in rack. When variable enter an average number.**(15).**

Life : it is the value (hours) which can be reasonnably expected. Because of the unavoidable dispersion in manufacture it should not be considered as absolutely certain but as a reasonnable figure to be expected. Since a global life figure has been entered it is not necessary to enter a daily working time ; there is indeed no difference between ten years at 12 hours/day and five years at 24 hours/day.

(16) Shared torque : when one single pinion drives two wheels.

(17) Intermediate wheel : idler or jockey wheel. It is free on its shaft, is driven by a pinion and drives another pinion or wheel.

METHOD NFE 23-015

This method is the french proposal to ISO/TC. The simplified method as found at the end of the standard is used here.

It is not aplicable to internal gearing.

ISO quality number should be from 5 to 8.

(18) It introduces a reliability factor for application where more failures are accepted, or conversely when high reliability is required. The number Fi to be entered corresponds to a failure probability of 1/Fi. For example if Fi = 100 is entered (as it is in usual commercial applications), 1 failure out of 100 is to be expected.

It is a modern method well suited to commercial applications as usually encountered.

Datas and symbols

sigmaF basic stress factor for strength (N/mm²). See Help in line.

sigmaH basic stress factor for pitting (N/mm²). See Help in line.

NM material number. See Help in line.

ISO quality number from 5 to 8.

METHOD AGMA 2001-B88

It is probably the most advanced but however the most difficult to use. The new standard 2001 B88 has superseded the former standard 218.01.

The new standard provides a considerably wider range of values for Sac and Sat vs the material physical data (some 15 pages). In order to simplify the selection the old tables of 218.01 have been retained in this leaflet : their values for Sac-Sat are indeed a little more conservative and quite sufficient for commercial applications. Clearly the new standard can be referred to when necessary or wished.

The determination of the load distribution factors Cm-Km is difficult when using the analytical method : it is indeed uneasy to appreciate a true value for the lead mismatch **et**. The alternative empirical method is easier to handle and has therefore been introduced.

Both external and internal gears can be dealt with and a reliability factor can be introduced.

IMPORTANT : the AGMA quality number to be entered is not the same as the ISO one but is specified in AGMA 390. There is no strict correspondance between the ISO and AGMA systems, however an approximate equivalence can be found on Help in line.

The load distribution factors Km-Cm can be determined from the methods described in the standard. Some comments and explanations are given below.

(19) Empirical method (to be preferred when possible)

The following conditions are required :

- face width should be smaller than or equal to 2 x pinion reference pitch diameter.

- both elements should lie between the bearings (no overhanging).

- maximum face width 1016 mm (40").

- the contact under load must spread over the full face width.

Dimensions S1 and S are shown on Help in line.

Applications are to be classified in four categories :

- open gearing.

- commercial enclosed gear units.

- precision enclosed gear units.

- extra precision enclosed gear units.

AGMA does not give any further information or comment regarding these categories but clearly the usual commercial applications are to be classified in the second one.

(20) Analytical method

Due to unavoidable errors in elements assembly and leads (distorsion) the light load contact is punctual. Under load the contact spreads over as a line and should normally spread over the whole face width. GSPARALW advises when it does not and displays the ratio Fm/b where Fm is the actual loaded width of contact. The ratio Fm/b depends basically on the value of mismatch **et** explained below.

When calculating the strength capacity the tooth thickness reduction to provide the necessary backlash is taken in account.

Datas and symbols

et total lead mismatch between mating teeth. It represents the combined effects of the influences listed below except hertzian contact and bending deformation at the tooth surface :

- errors of lead in machining.

- errors in the alignment of the shafts.

- elastic deflections of mounting elements under load such as shafts, bearings, housings, foundations etc.

- bearing clearances.

- thermal expansion.

- centrifugal forces.

The value of **et** is very difficult to estimate and require very careful consideration : the calculated load capacity depends indeed widely on it. It therefore requires all the designer wisdom and experience.

Fm loaded width of contact. See above.

Qv AGMA quality number. Does not correspond to ISO quality number. See Help in line.

Sac allowable contact stress for pitting (N/mm²). See Help in line.

Sat allowable bending stress (N/mm²). See Help in line.

(22) Load sharing : accurate spur gears develop the most critical stress when the load is applied at the highest point of the tooth when a single pair of teeth is carrying all the load. Less accurate spur gears having errors that prevent two pairs of teeth from sharing the load may be most heavily stressed when the load is applied at the tip. See Help in line. This question is omitted with helical gears with overlap ratio > 1.

Miner's rule

The Miner's rule, although being not a part of the american standard AGMA 2001-B88, is however described and recommended in its appendix B. It provides an efficient way to determine the expectable life of a pinion and wheel set loaded by a repeated or single cycle incorporating several periods each of them of different torque and/or speed, including uniformly variable torque and/or speed.

This option is only applicable in conjunction with the AGMA 2001-B88 method. More details and instructions are given by clicking on **Help** of the corresponding form.

METHOD HENRIOT

It is very popular in France owing to the notoriety of its author.

It is very similar to NFE 23-015 although somewhat simplified. It is however quite reliable in most cases as usually encountered.

It allows treatment of both external and internal gears but does not introduce a reliability factor.

Datas and symbols

ISO quality number : 5 through 12.

sigmaH allowable surface stress (N/mm²). See Help in line.

sigmab allowable bending stress (N/mm²). See Help in line.

METHOD ISO 6336 - D

The standard ISO 6336 proposes four different versions of its method denoted from A to D, the first one being the most sophisticated but however the most difficult to use. The simplified version D is used here, sufficient for usual commercial applications.

More details and instructions can be obtained from the Help in line.

Intermediate factors.

The main intermediate factors used in the calculataions can be displayed for the four standards and a calculation sheet can be printed.

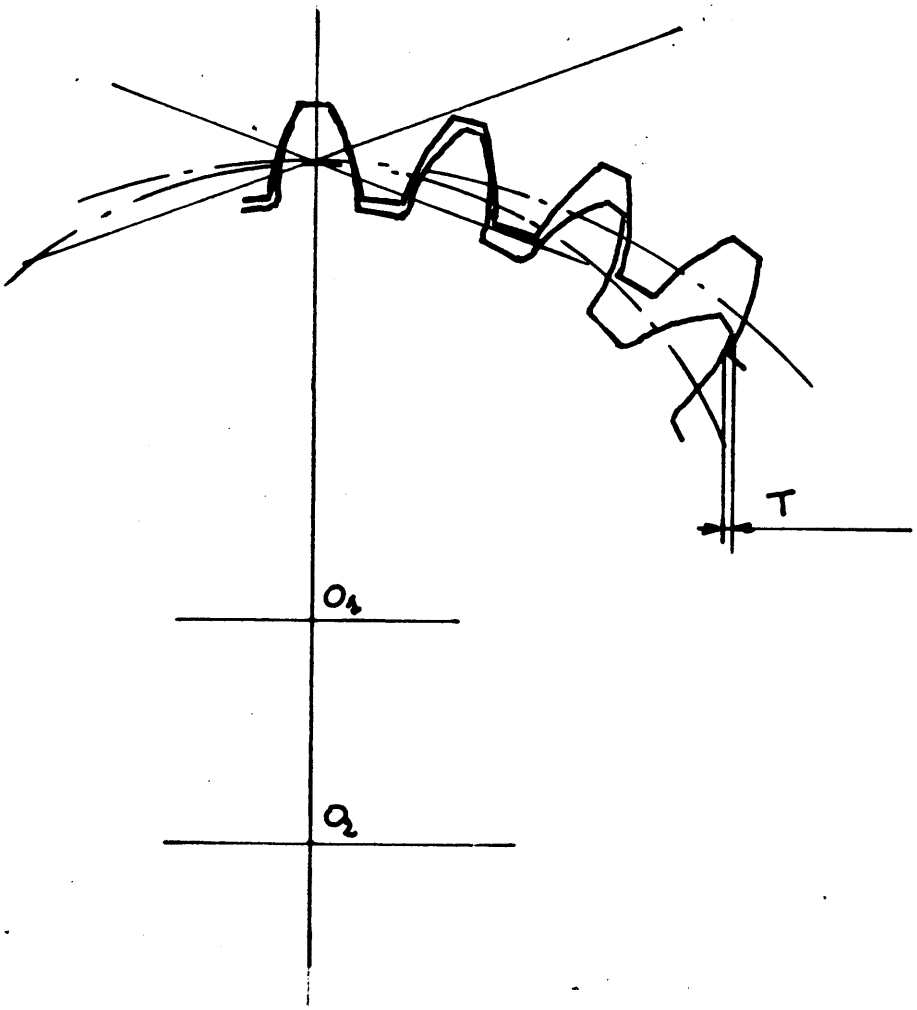

Fig. 1. - INTERNAL GEARS - T = TROCHOIDAL INTERFERENCE AND CUTTER TRIMMING

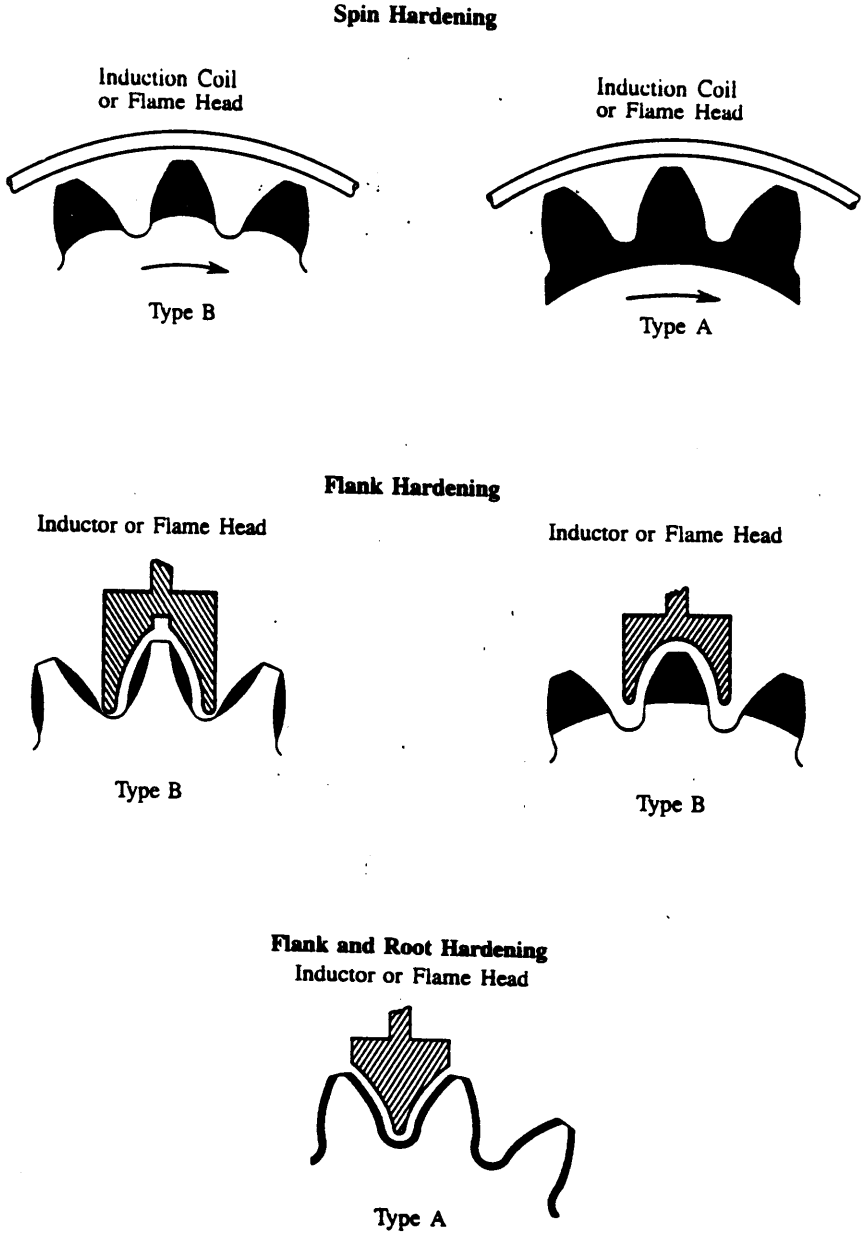

Fig. 4 - INDUCTION OR FLAME HARDENING